

## RATE CHANGES AFTER UNSCHEDULED OMISSION AND PRESENTATION OF REINFORCEMENT<sup>1</sup>

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Changes in response rate similar to frustration effects were studied in a two-lever situation. Responding on one lever on a fixed-interval schedule produced access to water for 5 sec and an exteroceptive stimulus. In the presence of this stimulus, responding on another lever on a fixed-interval schedule produced access to water for 5 sec and terminated the stimulus. Occasional omission of a previously scheduled reinforcer after responding on the first lever resulted consistently in increases in rate on the second lever during the immediately succeeding interval. In another procedure, occasional presentation of a previously unscheduled reinforcer after responding on the first lever resulted consistently in decreases in rate on the second lever during the immediately succeeding interval. Changes occurred after the first omissions or presentations and were about the same in magnitude as the procedure continued over several sessions. Typically, an increase or decrease in rate was maintained throughout an entire 100-sec interval. Changes in rate on the second lever of approximately the same magnitude also occurred when rate on the first lever was near-zero under a schedule that differentially reinforced behavior other than lever pressing.

Although frustration effects have been studied extensively in the double-alley runway situation (Amsel and Roussel, 1952; Amsel, 1958; etc.), there has been relatively little systematic study of rate changes resulting from omission of reinforcement in a free-operant situation. Rate increases after non-reinforcement have been observed in monkeys (Davenport and Thompson, 1965), in pigeons (Staddon and Innis, 1966, 1969; Crossman, 1968; Hamm and Zimmerman, 1967), and in rats (Staddon and Innis, 1969). In these experiments, rate in a schedule component after non-reinforcement was usually higher than rate in a component after reinforcement. Staddon and Innis (1969) identified the effect in fixed-interval schedules (FI 2-min) as decreases in the time before the occurrence of the first response after omission of reinforcement.

An opposite procedure, presentation of a previously unscheduled reinforcer, has not been investigated systematically, although in the above studies rate sometimes decreased abruptly in periods just after reinforcement. An example of an omission procedure is a change from a multiple to a chained schedule.

Reinforcement that has occurred regularly in one schedule component is omitted, and rate during the next period in the other component is recorded. The opposite procedure is represented by a change from a chained to a multiple schedule. Reinforcement that has occurred regularly only after completion of both components of a chain can be presented after the initial component, and change in rate in the second component can be recorded.

The present experiment, using a two-lever situation, examined rate changes resulting from both omission of a previously scheduled reinforcer and presentation of a previously unscheduled reinforcer. Responding on each lever was reinforced according to fixed-interval schedules, and the changeover from one lever to the other was controlled by an exteroceptive stimulus. Both multiple and chained schedules could be arranged in this situation, which also was somewhat analogous to the double-alley runway. The experiment used a probe technique in which omissions or presentations occurred occasionally after a stable pattern of responding had developed and in which monetary changes could be observed readily in individual rats.

In addition, the schedule on the first lever was manipulated, in order to determine whether or not rate changes on the second

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lever depended on behavior preceding omission or presentation of reinforcement. Under one procedure, responding on the first lever under a fixed-interval schedule ended in changeover to the second lever. In another procedure, responding in the first component under a schedule that differentially reinforced behavior other than lever pressing (DRO schedule) initiated the second component.

## METHOD

### Subjects

Four Sprague-Dawley male albino rats, about 90 days old at the beginning of the experiment, were given 1-hr daily sessions under 22-hr water deprivation. Dry food was continuously available in the home cages.

### Apparatus

The apparatus, described previously (Zimmerman, 1969*a, b*), was a modified Gerbrands Model C-3 chamber, enclosed in a ventilated ice chest. Two levers were located on opposite panels, 3.5 in. (9 cm) above the floor, and a liquid feeder was below and 2.5 in. (6 cm) to the left of lever 2. Stimuli consisted of two 7.5-v pilot lamps with white crystals. Responses were recorded on Gerbrands cumulative recorders.

### Procedure

During the first 12 sessions responding on both levers was established. At the end of this period the schedule was as follows. The first response on lever 1 operated the liquid feeder. After a 5-sec period of access to 0.1 cc of water, the dipper was lowered, and two white pilot lights on opposite panels came on. The first response on lever 2 in the presence of this exteroceptive stimulus again operated the feeder. Five seconds later the dipper lowered and the stimulus terminated. In the absence of the stimulus, the first response on lever 1 again produced water, and so on. Responses on lever 1 in the presence of the stimulus and on lever 2 in the absence of the stimulus had no scheduled consequences. Each lever operated a separate cumulative recorder.

Next, 100-sec fixed-interval schedules (FI 100-sec) were established on each lever. The first response on lever 1 after a 100-sec interval produced water for 5-sec, followed by the stimulus; then, the first response on lever 2 after

a 100-sec interval produced water for 5-sec and terminated the stimulus. These schedules continued for the next nine sessions. At the end of the period, responding was controlled by the lights; responses on the inappropriate lever occurred rarely and were not recorded.

Table 1 summarizes the conditions in the experiment. In all procedures the schedule on lever 2 was FI 100-sec, and on all occasions primary reinforcement occurred after lever 2 responding. Omissions and presentations of the reinforcer came after responding on lever 1; in addition, the reinforcement schedule on lever 1 was manipulated. Rate on lever 2 during intervals immediately after omissions or presentations of water was examined.

*Previously scheduled reinforcement omitted, FI schedule on lever 1.* The first procedure was similar to the omission procedure used by other investigators (Davenport and Thompson, 1965; Staddon and Innis, 1969). Figure 1 shows the sequence of events. Conditions in section A were in effect for nine sessions, followed by conditions in section B for seven sessions. Beginning in the twenty-second session, when responding on the FI schedule was stable, without systematic change from one day to another, reinforcement was omitted occasionally after responding on lever 1. On these occasions the only stimulus change at the end of the interval was onset of the lights controlling changeover to lever 2. The first response on lever 1 after 100-sec produced the lights, but no water, and the first response on lever 2 after 100-sec produced water and terminated the lights. On

Table 1  
Summary of Procedures

<i>Schedule on Lever 1</i>	<i>Reinforcement after Responding on Lever 1</i>	<i>Sessions</i>
FI 100-sec	presented	13-21
FI 100-sec	occasionally omitted	22-28
Tand FT 94-sec		
DRO 6-sec	presented	29-35
Tand FT 94-sec	occasionally omitted	36-42
DRO 6-sec		
FI 100-sec	omitted	43-49
FI 100-sec	occasionally presented	50-56
Tand FT 94-sec		
DRO 6-sec	omitted	57-63
Tand FT 94-sec	occasionally presented	64-70
DRO 6-sec		

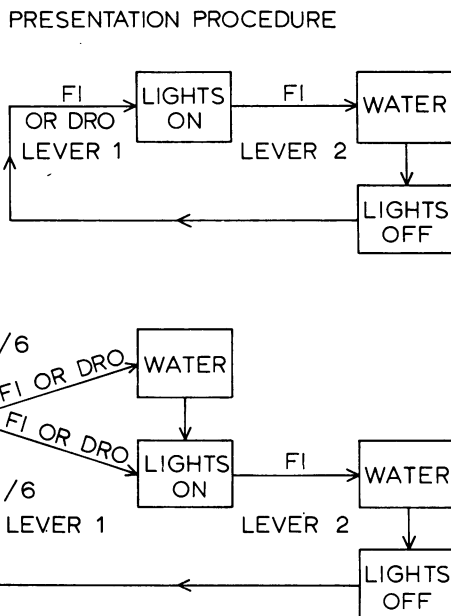
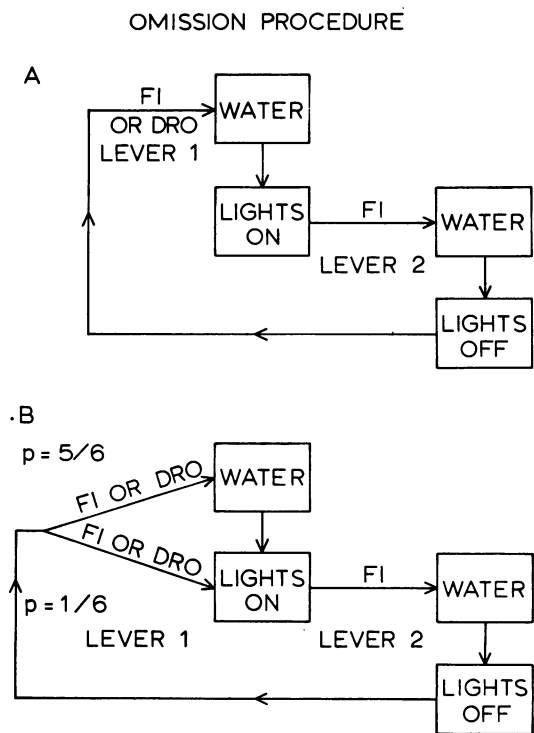


Fig. 1. Diagram of omission procedure. Conditions shown in section A were in effect first, for nine sessions, followed by conditions in section B, for seven sessions. In the second part of the procedure, on the average five out of every six intervals on lever 1 ( $p = 5/6$ ) ended with water and lights, and one out of every six intervals ( $p = 1/6$ ) ended with lights only. Entire experimental procedure (conditions in section A followed by conditions in section B) occurred first with FI 100-sec schedule on lever 1 and was repeated with Tand FT 94-sec DRO 6-sec schedule on lever 1.

Fig. 2. Diagram of presentation procedure. Conditions shown in section A were in effect first, for seven sessions, followed by conditions in section B, for seven sessions. In the second part of the procedure, on the average one out of every six intervals on lever 1 ( $p = 1/6$ ) ended with water and lights, and five out of every six intervals ( $p = 5/6$ ) ended with lights only. Entire experimental procedure (conditions in section A followed by conditions in section B) occurred first with FI 100-sec schedule on lever 1 and was repeated with Tand FT 94-sec DRO 6-sec schedule on lever 1.

the average, one out of every six regularly scheduled reinforcements was omitted after responding on lever 1 (about three during each daily 1-hr session). Omissions were scheduled by a stepping switch.

*Previously scheduled reinforcement omitted, DRO schedule on lever 1.* In the second procedure, rate changes on lever 2 were examined when the schedule on lever 1 differentially reinforced behavior other than lever pressing (DRO schedule). Except for the schedule on lever 1, which brought about a near-zero rate, the procedure was the same as before (as shown in Fig. 1). In the twenty-ninth session, the schedule on lever 1 was changed so that in the absence of the lights, water was presented regularly after 100-sec intervals, if a response on lever 1 had not occurred in the preceding 6-sec period at the scheduled time of presenta-

tion; otherwise, water was postponed for 6-sec by each response. In other words, a DRO 6-sec schedule was presented after a fixed time of 94 sec (tandem FT 94-sec DRO 6-sec). The schedule on lever 2 remained FI 100-sec. This procedure continued for seven sessions, which was sufficient to bring about a near-zero rate, without systematic change from one day to another.

Next, water was omitted occasionally; in the absence of the lights, an average of one out of every six intervals ended with presentation of the lights but no water, if a response had not occurred in the preceding 6-sec period. The procedure continued for seven sessions.

*Previously unscheduled reinforcement presented, FI schedule on lever 1.* In the third procedure, the opposite change, presentation of previously unscheduled reinforcement, was examined. Figure 2 shows the sequence of events. Conditions in section A were in effect for seven sessions, followed by conditions in section B for seven sessions. Thus, a chained

schedule was first established, with the lights controlling changeover from the first lever to the second and primary reinforcement following only the terminal response on lever 2. The schedule on each lever was FI 100-sec; that is, the overall schedule was Chain FI 100-sec FI 100-sec. The procedure continued for seven sessions. Next, reinforcement was presented occasionally after responding on lever 1; an average of one out of every six intervals ended with the lights and water, while all other intervals ended with the lights, but no water. The presentation procedure continued for seven sessions.

*Previously unscheduled reinforcement presented, DRO schedule on lever 1.* Finally, in the fourth procedure, effects of presentation were examined when the schedule on lever 1 was Tand FT 94-sec DRO 6-sec. Except for the DRO schedule on lever 1, which again resulted in a very low rate, the procedure was the same as before (as shown in Fig. 2). First, the schedule on lever 1 was changed to Tand FT 94-sec DRO 6-sec for seven sessions. Each 100-sec interval on lever 1 ended with the lights, but no water, if a response had not occurred in the preceding 6-sec period, while responding on lever 2 produced water on FI 100-sec. Then, for seven sessions, reinforcement was presented occasionally after responding on lever 1.

## RESULTS

Responding was positively accelerated under the FI 100-sec schedules. When water came regularly after responding on both levers, rate on both levers was high. When water came after responding on lever 2, while the lights, but no water, came after responding on lever 1, the rate on lever 1 was considerably lower. A low rate in the initial component is a frequently encountered characteristic of chained schedules (see, for example, Kelleher, 1966). Hence, before omissions and presentations, the patterns of responding were typical of multiple schedules and chained schedules.

When reinforcement was omitted occasionally at the end of the interval on lever 1, after it had been scheduled regularly during preceding sessions, rate on lever 2 in the intervals just after omission increased markedly. Repeated omissions throughout seven sessions had a similar effect. The magnitude of the change was approximately the same through-

out the period. Increases in rate were apparent in individual fixed-interval segments of the cumulative records in about two out of three instances. Typically, the higher rate was maintained throughout the entire 100-sec interval on these occasions.

Figure 3 shows representative cumulative records (Rat K-21). The first omissions were at the arrows in section A of Fig. 3. Section B shows performance six days later, after three omissions on the average in each daily 1-hr session. The figures show responding on both lever 1 (lower record in each section) and lever 2 (upper record in each session). Since responses on each lever operated a separate cumulative recorder, the fixed-interval segments in the lower records in each section alternated with segments in the upper records. Each recorder operated only during the stimulus condition when responses on the corresponding lever were appropriate.

In the first session in which reinforcement was presented after responses on lever 1, when it had not come regularly in preceding sessions, rate on lever 2 decreased markedly in the intervals just after presentation. Again, the effect was evident in individual record segments in many instances. The magnitude of the change in each interval was approximately the same throughout seven sessions. Section C of Fig. 3 shows performance in the first session under the presentation procedure, and section D shows performance six days later.

Figure 4 shows results of the procedures in which the DRO schedule was in effect on lever 1 (Rat K-21). When responding on lever 1 was reinforced on Tand FT 94-sec DRO 6-sec, rate on lever 1 decreased to near zero (lower records in each section of Fig. 4). Omissions and presentations of reinforcement (indicated by arrows in upper records of each section of Fig. 4) resulted in changes in rate on lever 2 similar to those found under the FI schedule on lever 1.

In all procedures, changes in rate were about the same throughout the seven sessions. There were some variations in overall rate from one session to another, but increases or decreases in rate were consistent in almost all instances. Figure 5 shows the mean response rate on lever 2 in intervals after omission and after presentation during the first session and during the seventh session under each procedure. Each bar indicates the mean rate in all intervals throughout one daily session. In all cases, rate

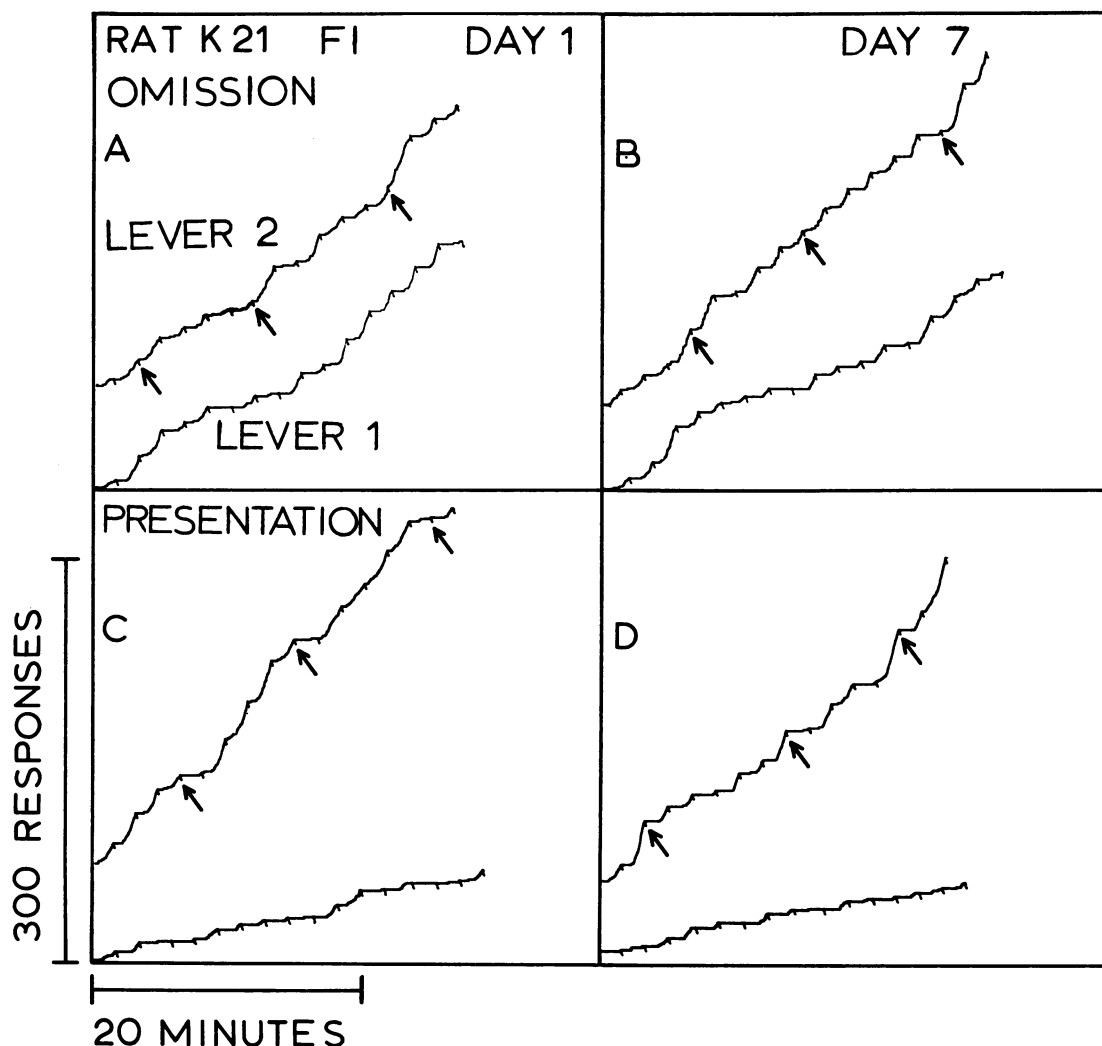


Fig. 3. Representative cumulative records of responding in first session and in seventh session with omission and presentation of reinforcement under FI schedule on lever 1 (Rat K-21). Left-hand sections (A and C) are Day 1 and right-hand sections (B and D) are Day 7. Upper sections (A and B) are omission procedure, and lower sections (C and D) are presentation procedure. Lower record in each section is responding on lever 1, and upper record is responding on lever 2. Fixed-interval segments in upper and lower records alternate. Exteroceptive stimulus change is indicated by downward movement of recorder pen. In sections A and B, omission of reinforcement after responding on lever 1 is indicated by arrows, and in sections C and D presentation of reinforcement after responding on lever 1 is indicated by arrows. Sections A and B: lights and water presented regularly after responding on lever 1 on FI 100-sec, and water omitted at beginning of intervals of responding on lever 2 preceded by arrows. Sections C and D: lights presented regularly after responding on lever 1 on FI 100-sec, and lights and water presented at beginning of intervals of responding on lever 2 preceded by arrows.

increased after omission and decreased after presentation in both the first and the seventh sessions. Although there was considerable variability in overall rate between these two sessions in several cases, the magnitude of the change was usually about the same.

Figure 6 indicates changes in pattern of responding under all procedures. The figure

shows mean response rate on lever 2 in each quarter of the 100-sec interval over all intervals throughout seven sessions. Typically, rate was higher in all four quarters of the interval after omission and lower in all four quarters after presentation. The effect was similar under both FI schedules and DRO schedules on lever 1. Usually, the absolute magnitude of the

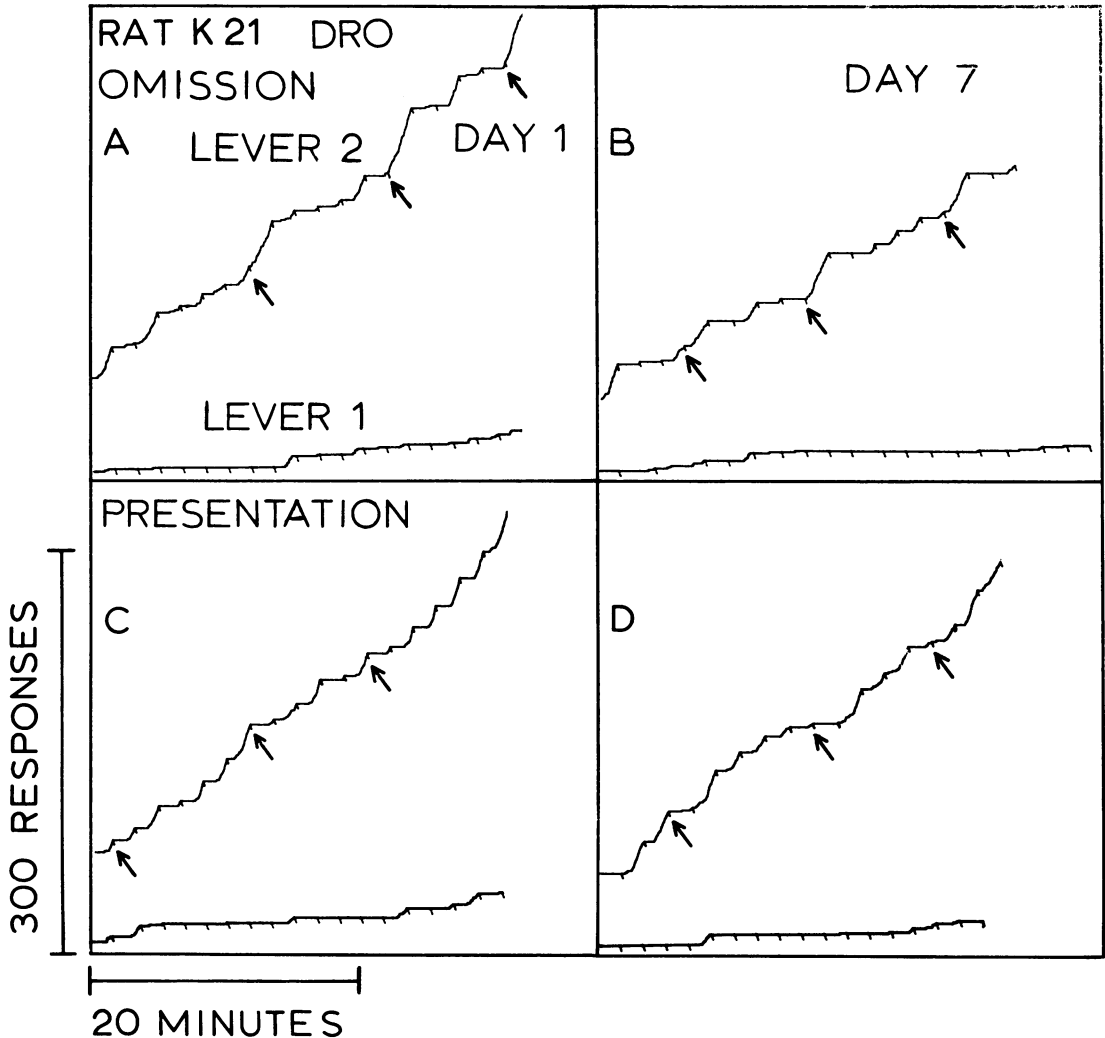


Fig. 4. Representative cumulative records of responding in first session and in seventh session with omission and presentation of reinforcement under DRO schedule on lever 1 (Rat K-21). Sections A and B: lights and water presented regularly after responding on lever 1 on Tand FT 94-sec DRO 6-sec, and water omitted at beginning of intervals of responding on lever 2 preceded by arrows. Sections C and D: lights presented regularly after responding on lever 1 on Tand FT 94-sec DRO 6-sec, and lights and water presented at beginning of intervals of responding on lever 2 preceded by arrows.

difference in rate was greatest in the third quarter of the interval. In about half of the cases, the magnitude of the change was different in the four quarters of the interval, and the pattern of fixed-interval curvature was disrupted.

#### DISCUSSION

The rate changes observed were similar to those found by other investigators in various omission procedures in the operant situation

and were also similar to frustration effects in the double-alley runway. Changes in rate in the second schedule component occurred in the present experiment in both omission and presentation procedures and were independent of the schedule controlling behavior in the first component. Rate increased consistently after omission of a reinforcer and decreased consistently after presentation of a reinforcer.

In double-alley runway experiments, omission of the reinforcer at the end of the first alley results in an increase in running speed

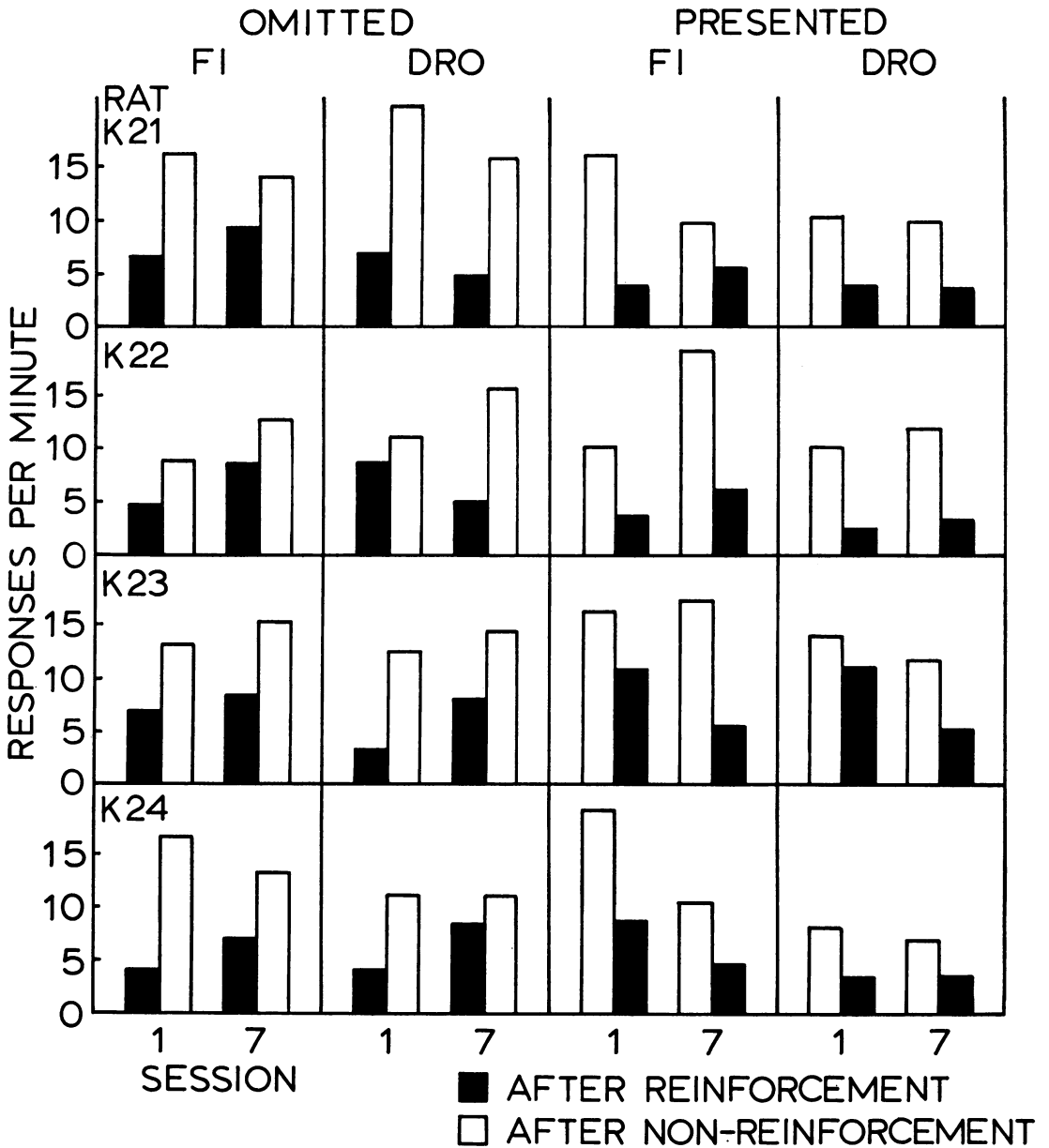


Fig. 5. Mean response rate on lever 2 in 100-sec intervals immediately after reinforcement and immediately after non-reinforcement during first session and during seventh session of each procedure. Rates in intervals after reinforcement are indicated by solid bars, and rates in intervals after non-reinforcement are indicated by open bars. Rates during first session are indicated by left-hand pair of bars in each section, and rates during seventh session are indicated by right-hand pair of bars in each section. In the two sections on the left, reinforcement was omitted occasionally after being scheduled regularly during the preceding sessions. In the two sections on the right, reinforcement was presented occasionally after being unscheduled during the preceding sessions. In the two sections labelled FI at the top the schedule on lever 1 during the preceding seven sessions and during the seven sessions represented in the figure, was FI 100-sec. In the two sections labelled DRO at the top the schedule on lever 1 during the preceding seven sessions and during the seven sessions represented in the figure was Tand FT 94-sec DRO 6-sec.

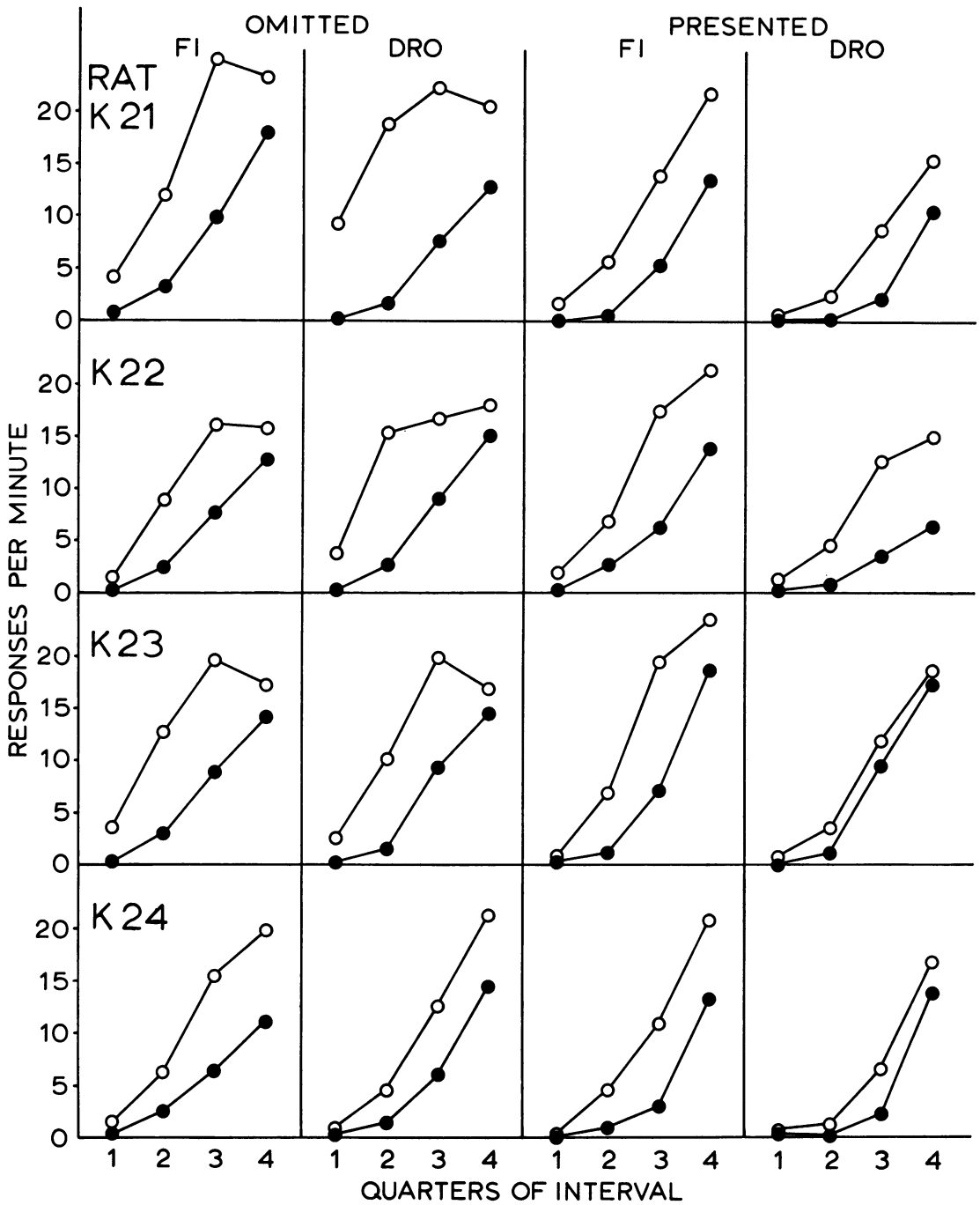


Fig. 6. Mean response rate on lever 2 in each quarter of 100-sec intervals immediately after omission of reinforcement (open circles) and immediately after presentation of reinforcement (solid circles) at end of interval of responding on lever 1. Each point represents mean rate over seven sessions. Experimental conditions were same as in Fig. 5.



in the second alley (Amsel and Roussel, 1952; Amsel, 1958). In the present situation, omission of the reinforcer after responding on one lever resulted in an increase in rate and a change in pattern of responding on a fixed-interval schedule on another lever. Hence, in general features, the changes observed in the first part of the present experiment were similar to findings in runway studies.

Typically in double-alley runway studies, averages of latency or speed measures from one group of subjects are compared to averages from another group of subjects or to averages from the same subjects under different conditions in the presence of different exteroceptive stimuli. In the present experiment, averages were taken over intervals after omission and presentation in individual rats, as an indication of change in rate and pattern of responding. It was found that changes occurred to some extent throughout the entire 100-sec interval. Also, the effect was apparent in individual fixed-interval segments of the cumulative records.

These effects were independent of the schedule controlling responding on lever 1. When reinforcement and the stimulus were presented on a DRO schedule, in which at least 6-sec had elapsed since the last response, rate became near zero on lever 1, but effects of omissions and presentations of the reinforcer on rate on lever 2 were similar. Hence, rate increases and decreases on the second lever occurred consistently under quite different schedules on the first lever, even when one schedule reinforced responding other than lever pressing. These findings suggest that the effect was controlled by the event of reinforcement or non-reinforcement independently of the behavior preceding the event.

Staddon and Innis (1969), using a method in which a brief blackout occurred in place of reinforcement on a FI 2-min schedule, found marked increases in rate in intervals after omissions. These were accounted for largely by a decrease in the time to the first response after the blackout. In the records presented by Staddon and Innis, the fixed-interval pattern was usually an abrupt change from non-responding to a relatively constant rate, and marked changes in the "running rate" in the latter part of the interval did not appear. In the present experiment, rates in successive quarters of a 100-sec fixed-interval were re-

corded, and there was an increase throughout the entire interval, including the "running rate". Similar changes were found in all four procedures in the present experiment.

The fact that rate increased after non-reinforcement and decreased after reinforcement suggests a relationship of these changes to contrast effects (Reynolds, 1961; Hamm and Zimmerman, 1967). Contrast is observed frequently in multiple schedules, a decrease in rate in one component in the presence of an exteroceptive stimulus being accompanied by an increase in rate in another component in the presence of another stimulus. In the present experiment, however, rate increased abruptly after omissions, that is, after a momentary change from a multiple to a chained schedule, and increased repeatedly after omissions even though these previously unscheduled events came after only one out of every six intervals on the average. It is not likely that non-reinforcement of lever 1 responding on one out of six occasions resulted in a discrimination of the kind that accompanies contrast effects in multiple schedules. Also, Staddon and Innis (1969) found similar changes in a procedure which omitted one out of every four reinforcements. These results are unlike the gradual development of contrast effects observed in multiple schedules (Reynolds, 1961).

Frustration and facilitation effects have been considered by some investigators as a possible explanation of conditioned reinforcement (Bugelski, 1956; Schuster, 1969; *etc.*). According to one interpretation, a frustration effect resulting from omission of primary reinforcement that has previously accompanied a stimulus accounts partly or entirely for an increased rate of responding in conditioned reinforcement. According to another interpretation, the discriminative control of a stimulus that has been associated with primary reinforcement facilitates or enhances rate of responding. Although these concepts are sometimes invoked to explain conditioned reinforcement, there has been relatively little attempt to manipulate facilitation or frustration directly in operant situations. The present results, and those of other recent studies, show that large rate increases can follow omission of primary reinforcement under some conditions.

For this reason, the present findings emphasize the importance of studying conditioned

reinforcement schedules in which changes in pattern of responding, as well as changes in rate, are examined. Several experiments that have investigated "schedule effects" (Kelleher, 1966; Stubbs, 1969; Byrd and Marr, 1969; Zimmerman, 1969a, b; etc.) have found changes in the pattern of responding under conditioned reinforcement schedules that cannot be explained easily by frustration or facilitation. For example, conditioned reinforcement presented on a DRO schedule can bring about a decrease in rate instead of an increase. Changes of the kind found in the omission procedure in the present experiment could account for enhancement of rate of responding, but not for a change in pattern of responding appropriate to the schedule of presentation of a stimulus.

In summary, the present evidence suggests that the rate changes in both the omission and presentation procedures are independent of behavior in the schedule component preceding occasions on which the reinforcer is omitted or presented. It suggests also that the effect occurs immediately after the procedure begins and continues to occur in about the same magnitude for at least seven 1-hr sessions. Finally, an increase or decrease in rate persists for at least a 100-sec interval. These findings cannot be explained easily either in terms of a general motivational state, or by behavioral contrast. If discriminative control by the event of reinforcement or non-reinforcement is important, it must be hypothesized that control extends over at least a 100-sec period. While rate changes of this kind could conceivably explain why conditioned reinforcement schedules enhance rate of responding, apart from a contingency of a stimulus on behavior, they cannot account for changes in pattern of responding and "schedule effects" found in studies of conditioned reinforcement.

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